Flash Lidar Performance Testing – Configuration and Results

Ilya Poberezhskiy, Andrew Johnson, Daniel Chang,

Eric Ek, David Natzic, Gary Spiers

Jet Propulsion Laboratory, California Institute of Technology

Steve Penniman, Brad Short
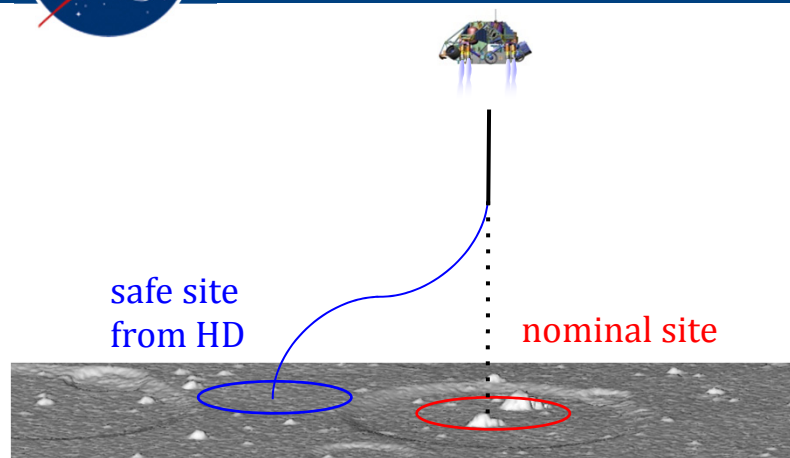
Advanced Scientific Concepts, Inc

Presentation # 8379-4

Outline

- Motivation: why Hazard Detection?

- HD Lidar for Mars Lander

- ASC GoldenEye Flash Lidar Overview

- Lidar Test Setup

- Test Results:

  – Lidar noise parameters
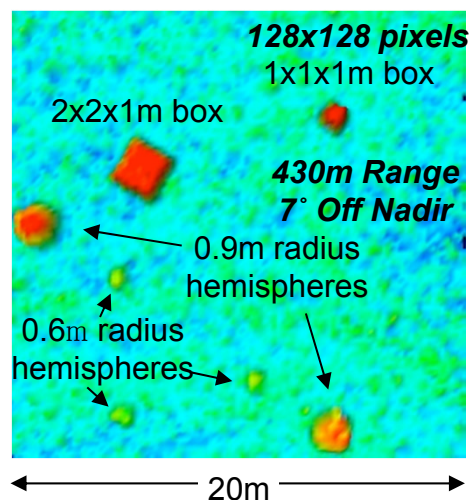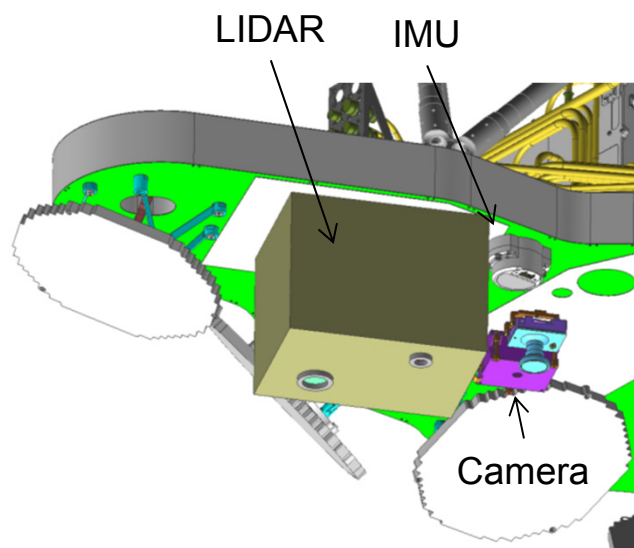
  – Resolving representative hazards of known shape

- Conclusion

Motivation: why HD?
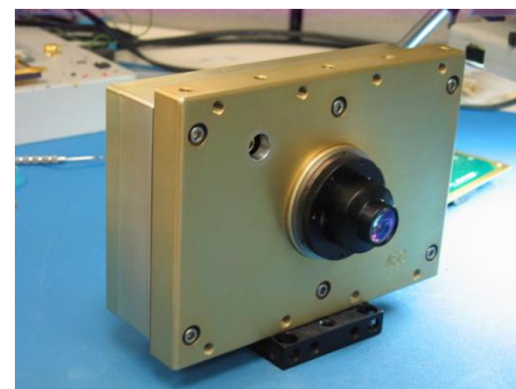
HD detects small hazards (e.g. rocks) not visible from orbit and directs the lander to target the safest visible landing site

HD Components:

- HD lidar generates an elevation map from one image
- HD algorithm identifies safe sites free of rocks and slopes
- Processing can be performed on existing flight computer or a separate compute element

safe site from HD

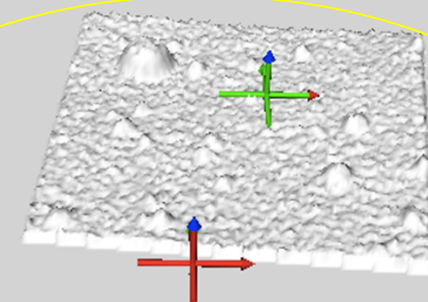nominal site

local terrain around touch down

LIDAR   IMU

Camera

128x128 pixels
1x1x1m box

2x2x1m box

430m Range
7° Off Nadir

0.9m radius hemispheres

0.6m radius hemispheres

20m

Example Flash Lidar Image

Flash lidar (ASC GoldenEye)

Example of HD Simulation

Selected safe landing site
(true safety=0.998)

Nominal landing site

HD Divert Capability (10m)

Reconstructed DEM (single 128x128 image, 8 cm range noise)

HD Lidar for Mars Lander

- As part of Mars 2018 technology development, we selected the following preliminary parameters for the lander HD system:
    - DEM acquisition starts at 200 m
    - Nadir pointing, 10-20 m diameter FOV
    - 1 sec for data collection + 1 sec for processing before starting divert
- These parameters guided our lidar test configuration
- In principle, both flash or scanning type lidars could work for this task:

|	Advantages	Drawbacks
Flash Lidar	• Single-shot acquisition of all 3D points – don't need IMU input to "stitch together" DEM • No need for beam scanner	• Higher per-pixel range noise • Less range for same pulse energy • Cross-talk between pixels
Scanning Lidar	• Lower range noise • Greater range for same pulse energy • Adjustable FOV (sometimes)	• Lander moves while data is collected – need IMU input to reconstruct DEM • Need beam scanner

ASC GoldenEye Flash Lidar Overview

Latest in a series of ASC flash lidar cameras:

- TigerEye (commercially available)
- DragonEye (has flown on 2 STS missions, Space X Dragon)
- GoldenEye (separate new laser; electronic parts w/ S-rated equivalents)

Key parameters:

- 128x128 pixel focal plane array
- 1570nm w/OPO, 1064nm w/o OPO
- 11 mJ per pulse (~20mJ w/o OPO)
- will drop OPO for HD lidar – more pulse energy, simpler laser
- ≤ 20 Hz rep rate with real-time output of 3D point cloud to computer
- laser and receiver <3kg combined
- Tested with 3°, 8.6° FOV optics

GoldenEye Lidar Camera

Q-switched Laser with Diffuser
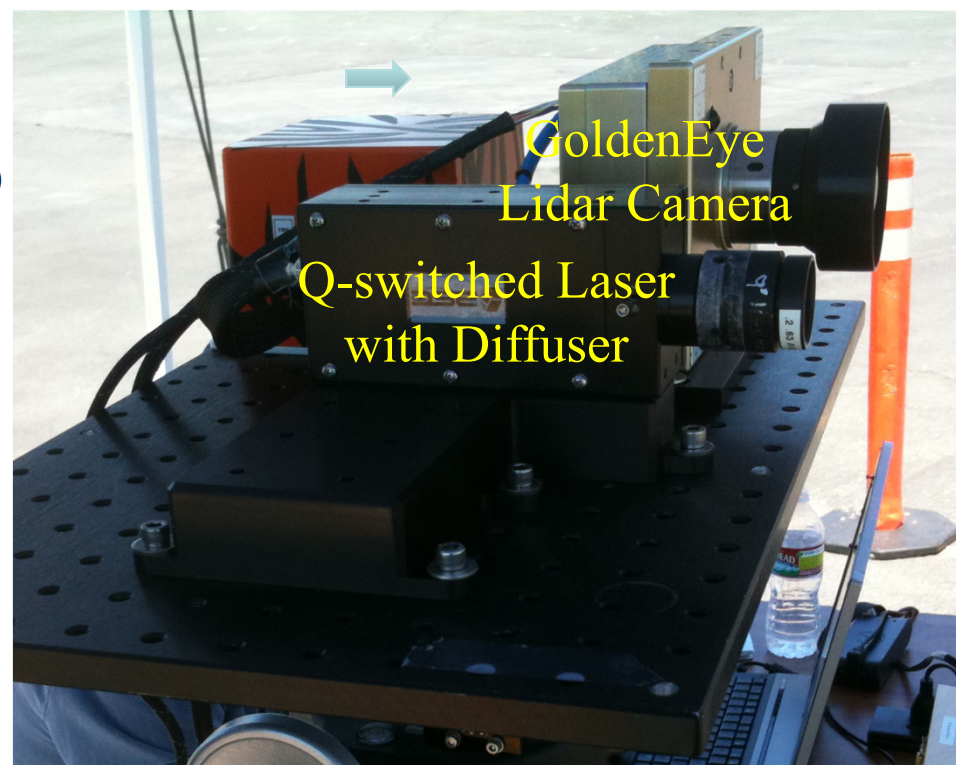
Lidar Test Setup [1]

- 200 m range at JPL MESA test site
- 3 flat 4'x8' target boards with nominal albedo of 4%, 14% (good approx. for Mars) and 30%
- Target rotates about vertical axis to vary incidence angle
- Added varying hemispheric targets of 6" – 24" height
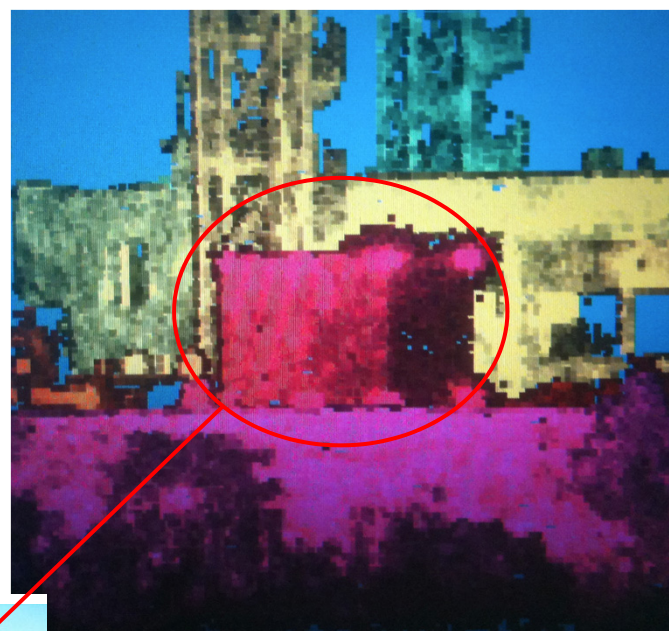- Total station measures true positions of lidar and target optical fiducials

Lidar Test Setup [2]

- Sample data shown below for 3° FOV optics with 60% attenuator
- Note: much higher optical return from the corner cubes affects neighboring pixels, which we therefore drop in post-processing

Grey scale intensity image

1 frame of color-coded distance data

Test results – 3° FOV, Flat Targets [1]

- True range (measured by Total Station) = 199.85 m
- Parameter definitions and discussion on the next slide…

Pulse Energy [mJ]	Nominal Patch Albedo [%]	Mean Intensity [counts]	Intensity Standard Deviation [counts]	Mean Range [m]	Per-Pixel Range Noise [cm]	Bias Noise Across Patch [cm]
11	30	2356	157	199.90	4	2
11	14	2095	230	199.98	5	3
11	4	846	135	200.07	22	5
7.4	30	1787	295	200.06	6	2
7.4	14	1353	305	200.10	10	3
7.4	4	-	-	-	-	-
3.3	30	1154	231	199.90	10	3
3.3	14	913	205	200.03	17	3
3.3	4	-	-	-	-	-

- *Bias Noise Across Patch* – describes overall frame to frame variation in range across the patch

- *Per-Pixel Noise* – takes out best fit plane from each frame and measures range errors with respect to this plane; frame to frame range biases don't appear in this metric. **This metric is the critical one for HD and our preliminary requirement for this metric is 8 cm.**

- **Per-pixel noise is ≤ 6 cm for patches with median intensity > 1500 counts,** deteriorates rapidly when intensity drops below 1000 counts
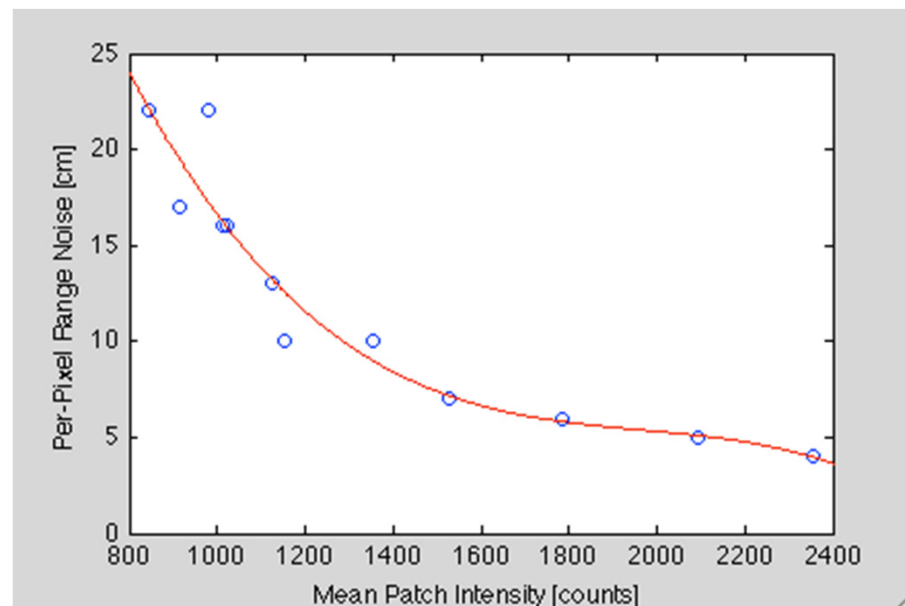
True range measured with Leica Total Station = 199.85m (true range variations between pixels <2 cm)

Absolute accuracy is better than 25 cm
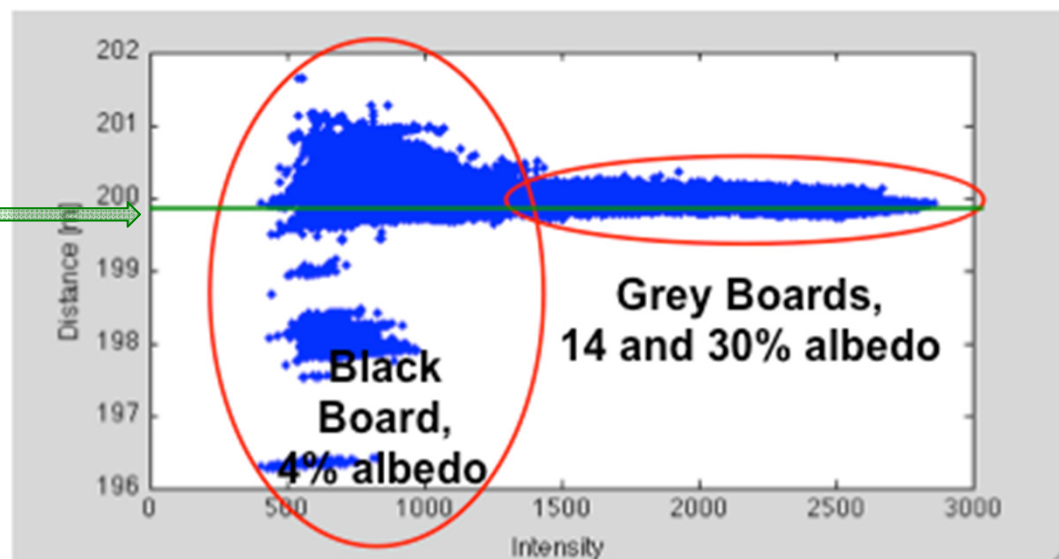
Test Results: 9° FOV Optics

Pulse Power [mJ]	Nominal Patch Albedo [%]	Mean Intensity [counts]	Intensity Standard Deviation	Mean Range [m]	Per-Pixel Noise [cm]	Bias Noise Across Patch [cm]
11	30	605	124	199.40	46	15

- 9° FOV performance not adequate under optimal conditions above – much poorer still for lower albedos and attenuated pulses

- Reason: optical efficiency suffers for 8.6 FOV receiver optics because its F# is poorly matched to F# of the microlenses in front of FPA

- **Thus, although FOV can be easily changed by swapping the receiver lens and laser diverger, the resulting impact on performance is significant**
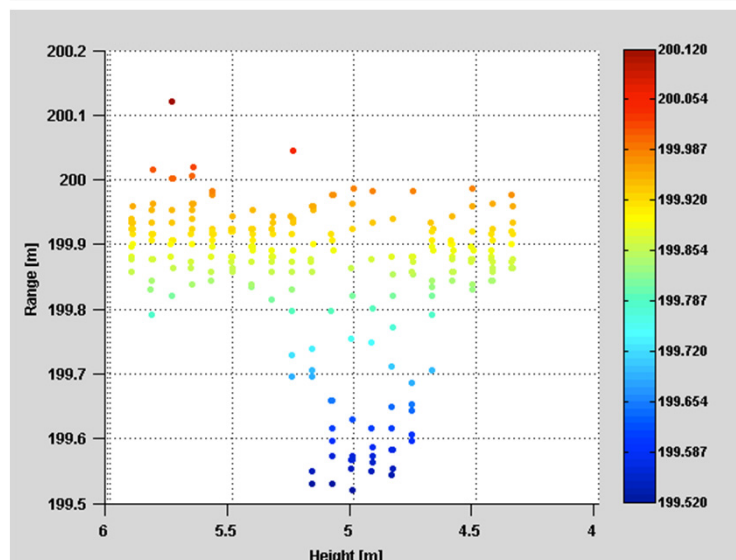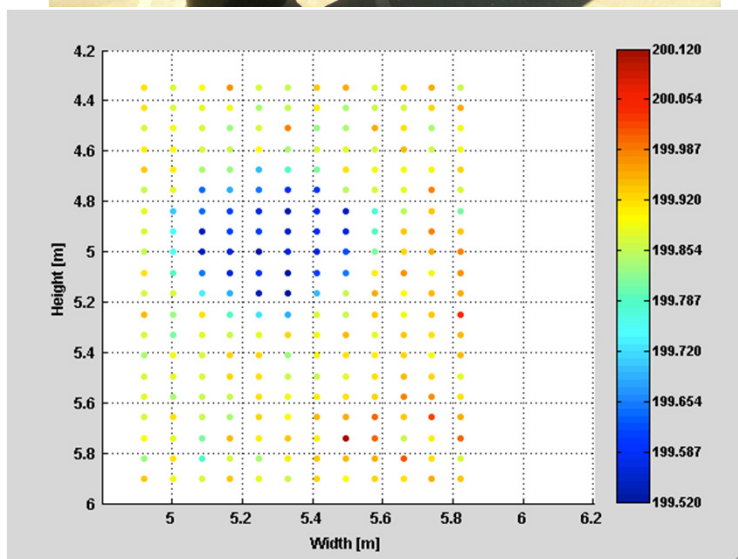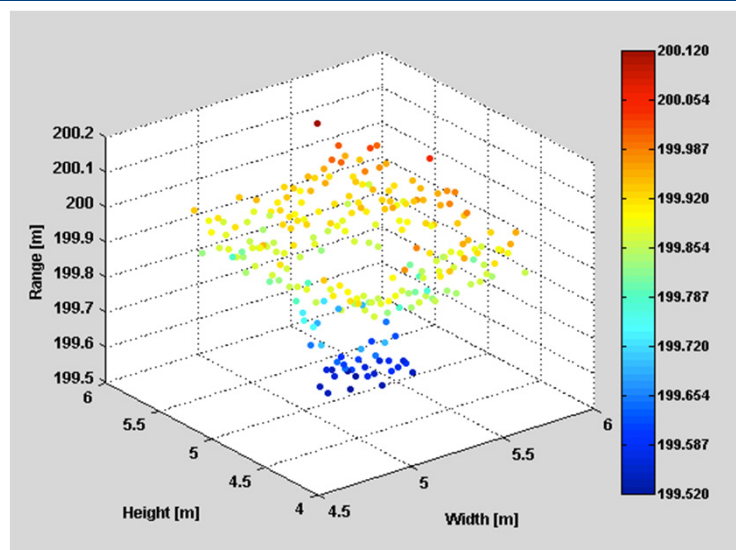
- **30 cm tall hemispheric hazard resolved very well**

- 20 cm tall hemispheric hazard is clearly visible in the 3D point cloud
- All hemispheres have 14% albedo
- Data acquired with 3° FOV optics
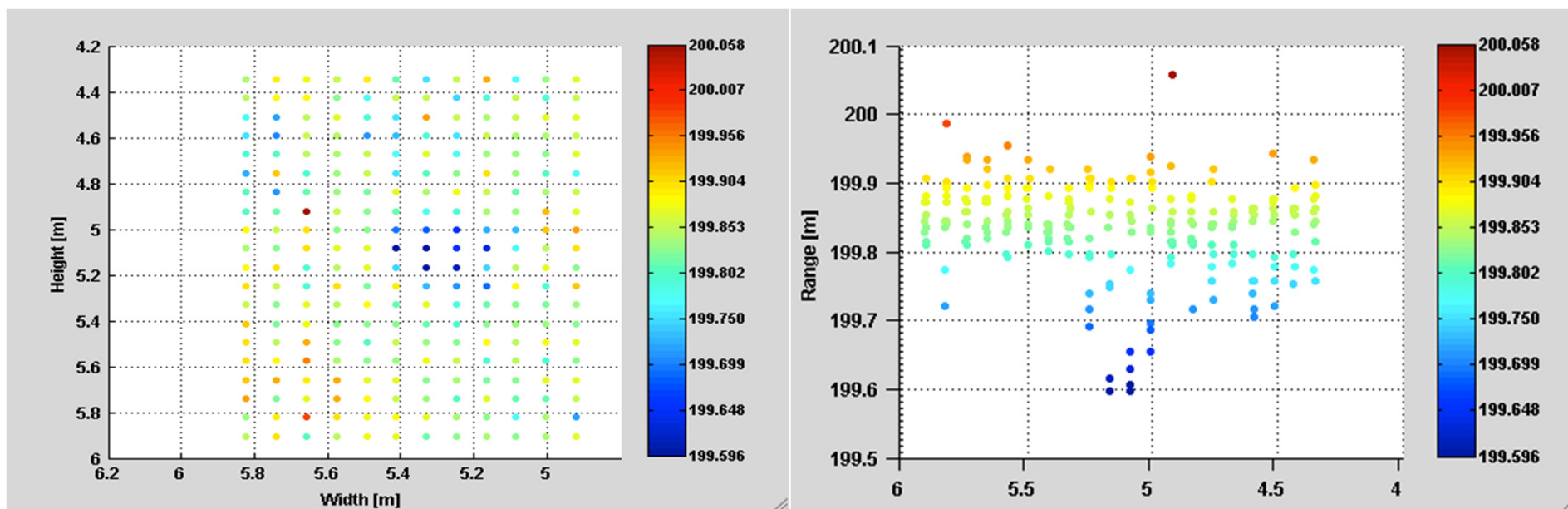
Conclusion

- Lidar-based hazard detection and avoidance will enable safe landing in scientifically interesting terrain with higher hazard abundance
- ASC GoldenEye flash lidar was tested at JPL as part of EDL technology development for Mars 2018
- Per-pixel range noise (taking out frame bias variations) identified as key HD lidar performance parameter, preliminary requirement = 8 cm
- With 3° FOV optics, GoldenEye demonstrates per-pixel noise ≤ 6 cm for Mars-like albedo board (~15%) at 200 m and better than 25 cm absolute range accuracy
- This per-pixel noise performance corresponds to per-pixel intensity >1500 counts, and degrades rapidly when per-pixel intensity drops below 1000 counts
- Lidar resolves hemispheric hazards with height ≥ 20 cm at 200m
- Dropping OPO will nearly double laser pulse energy and reduce laser complexity